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Peanut leaf area index, light interception, radiation use efficiency, and harvest index at three sites in Texas

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Abstract

Stability of parameters describing crop growth of peanut (*Arachis hypogaea* L.) is important because of the diversity of climatic conditions in which peanuts are grown and is valuable when developing simulation models for this species. In contrast, variability in the same parameters is desirable for plant breeders working to develop improved cultivars. This study seeks to quantify key parameters for biomass and yield production of some common peanut cultivars at three sites in Texas. We measured leaf area index (LAI), light extinction coefficient (k) for Beer's law, and harvest index (HI) for four cultivars at Stephenville, TX and one cultivar near Gustine, TX, and for LAI and biomass on four cultivars at Seminole, TX. Mean radiation use efficiency (RUE) values were 1.98 g MJ^{-1} at Stephenville, 1.92 at Gustine, and 2.02 at Seminole. Highest RUE values were for the Low-Energy Precise Application (LEPA) irrigation treatment at Seminole. Maximum LAI values ranged from 5.6 to 7.0 at Stephenville, from 5.0 to 6.2 at Seminole, and was 5.3 at Gustine. Mean k values ranged from 0.60 to 0.64 at Stephenville and was 0.77 at Gustine. The overall mean HI was 0.36, with a mean of 0.33 for Stephenville, 0.44 for Gustine, 0.53 for spray irrigation at Seminole, and 0.58 for LEPA irrigation at Seminole. Values of RUE, k, and HI for the cultivars in this study and similarities between this study and values reported in the literature will aid modelers simulating peanut development and yield and aid breeders in identifying key traits critical to peanut grain yield improvement.
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1. Introduction

Peanut production in the U.S. occurs from humid areas of Georgia and Florida to arid areas of the southern High Plains of Texas. Peanut production in the semi-arid region of western Texas near Seminole offers an opportunity to test the stability of parameters describing plant growth that were developed in more

Abbreviations: FIPAR, fraction of photosynthetically active radiation intercepted by plants; GROWTH, plant growth rate, g per plant per day; HI, harvest index; IPAR, photosynthetically active radiation intercepted by plants, MJ per plant per day; k, light extinction coefficient for Beers Law; LAI, leaf area index; LEPA, low-energy precise application; PAR, photosynthetically active radiation, MJ m^{-2} per day.

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humid, high rainfall areas such as the southeastern U.S. This western environment has high evaporative demand, high vapor pressure deficit, low rainfall, and high yield potential when irrigated. Parameters and functions that are stable in this environment as well as in more humid regions can be accepted as more fundamentally sound for peanut modeling internationally. Likewise, when measured in this arid environment, if parameters and functions diverge from accepted norms, then additional research will be needed to determine causes of such difference. In contrast to researchers involved in crop modeling, plant breeders working to develop improved peanut cultivars desire variability in such parameters.

As discussed by Amthor and Loomis (1996), mechanistic models simulating cropping systems at one level are best described by processes at a lower level. Likewise, Sinclair and Seligman (2000) discussed how crop level simulation models should simulate processes at the whole-plant level and whole-plant simulation should be simulated at the organ level. Such process-based simulation models have been developed and applied for peanut by Boote et al. (1986), Hammer et al. (1995), Meinke and Hammer (1995), and Kaur and Hundal, (1999).

These models rely on accurate, robust functions for plant growth and development. All crops produce leaves, intercept light, and partition biomass into grain. By better quantifying parameters that describe these processes, peanut models can be developed that accurately simulate leaf area index, biomass, and seed production. However, despite the fact that peanut is a prominent crop species in parts of Texas, there is a paucity of information from this state to allow its simulation by such process-based models.

Peanut k values from the literature are similar to those of other common crops while maximum seasonal LAI tends to be greater than for most crops. Reported values for LAI (Table 1) range from 3 to greater than 8. The mean LAI from these eight studies was near 6. Likewise, realistic values for k provide accurate simulation of light interception using LAI. The mean k (±S.D.) from eight studies was 0.60 ± 0.13 (Table 1).

Reported RUE values for peanut (Table 2) are lower than for many common grain crops (Kiniry et

Table 1
Maximum LAI values during the season, mean light extinction coefficient (k) for the Beer's Law equation (see Section 2), and harvest index (HI) values from the literature

Location (source)	LAI	k	HI
Florida (Gardner and Auma, 1989)	3	0.80	–
Florida (Jaaffar and Gardner, 1988)	6.13 and 6.75	0.65	–
Florida (Bennett et al., 1993)	4.2	–	0.40 and 0.48
Florida (Jones et al., 1982, k calc. from results)	4.5–5.9	0.57	–
Florida (Pixley et al., 1990)	7.1 and 5.2	–	0.49
Florida (Duncan et al., 1978)	7	–	0.38
Florida (Selamat and Gardner, 1985)	7	–	–
Florida (Hang et al., 1984)	–	–	0.49
North Carolina (Wells et al., 1991)	–	–	0.46
Virginia (Coffelt et al., 1989)	–	–	0.47
Argentina (Collino et al., 2001)	4.2 and 6	0.74	0.44
India (Nageswara Rao et al., 1988)	5–6	–	–
India (Dwivedi et al., 1998)	–	–	0.40
Australia (Chapman et al., 1993a, k calc. from results)	7.0–8.5	0.37	–
Australia (Bell et al., 1994)	–	0.50	0.43
Australia (Bell et al., 1992)	–	0.53	–
Australia (Bell et al., 1993)	–	–	0.62
Australia (Wright et al., 1991)	–	–	0.46
Australia (Chapman et al., 1993b)	–	–	0.46
Indonesia and Australia (Bell and Wright, 1998)	–	–	0.41
Japan (Awal and Ikeda, 2003)	–	–	0.52
Mean ± S.D. using above values	5.9 ± 1.5	0.60 ± 0.13	0.45 ± 0.04

Table 2
Peanut RUE values at various locations in the literature

Location (source)	VPD (kPa)	Solar radiation (MJ m^{-2})	RUE (g MJ^{-1} IPAR)	Mean RUE for study (g MJ^{-1} IPAR)
India (Matthews et al., 1988)				
Drought stressed	–	–	0.89	0.89
Australia (Bell et al., 1993)				
	–	–	1.59	1.70
	–	–	1.60	–
	–	–	1.72	–
	–	–	1.91	–
Ontario, Canada (Bell et al., 1994)				
1991	0.93	19.3	2.11	1.90
1992	0.69	18.0	1.69	–
Australia (Bell et al., 1992)				
Bundaberg	1.04	18.0	2.49	2.14
Kingaroy	1.14	23.2	1.79	–
Florida (Bennett et al., 1993)				
	1.62	18.1	2.22	2.22
Australia (Chapman et al., 1993a) overhead sprinkler irrigation				
	0.74	22.0	2.49–3.02	2.66
Argentina (Collino et al., 2001) drip irrigation				
	0.96	17.7	3.99 and 3.52	3.76
Australia (Bell et al., 1992)				
Warm greenhouse	–	–	4.60	4.08
Cool greenhouse	–	–	3.56	–

All were field studies with irrigation unless otherwise noted, mean ± S.D. without smallest and three largest means is 1.99 ± 0.20.

al., 1989), generally similar to values for rice (*Oryza sativa* L.) (Kiniry et al., 1989; Kiniry et al., 2001). Similar to cotton boll production (Thornley and Hesketh, 1972; Rosenthal and Gerik, 1991), peanut pod production requires more energy than production of vegetative organs. Thus we can assume that biomass values are the above ground biomass plus the pod weight times a 1.65 energy correction factor (Duncan et al., 1978; Wright et al., 1991). Using 0.45 for the factor to convert total solar radiation to photosynthetically active radiation (PAR) (Monteith, 1965; Meek et al., 1984), the RUE for eight diverse sites varied widely (Table 2). The lowest RUE was for a drought stressed study. There were three studies with relatively high values for RUE. One of these was in a greenhouse and two were field studies. The remaining four studies were from Australia, Canada, and Florida. These four showed some consistency in RUE, with a mean (±S.D.) of 1.99 ± 0.20 g MJ^{-1} intercepted PAR (IPAR). Causes for the relatively large RUE values in the bottom three studies warrant further research.

Reduced k values (more upright leaves) are important for allowing better light penetration into leaf canopies, thus illuminating more leaf area at a lower intensity of PAR, causing canopy carbon exchange rates to increase. This would be expected to increase the RUE when biomass is source-limited. Such a trend was reported for peanut RUE by Bell et al. (1993). Using different cultivars, different planting densities, and different planting dates, they demonstrated that as k increased from 0.3 to 1.0, RUE decreased from 2.75 to 1.5 g MJ^{-1}. Similar responses for diverse C_4 grasses were shown by Kiniry et al. (1999). Alamo switchgrass (*Panicum virgatum* L.) had high LAI and low k values, resulting in high RUE. In contrast, sideoats grama (*Bouteloua curtipendula* (Michaux) Torrey) had low LAI and high k values, resulting in much lower RUE.

Quantification of HI and causes for its variability, are vital for many yield simulation models. Peanut HI values from the literature (Table 1) varied greatly among cultivars, locations, seasons, and ecosystems, ranging from 0.38 to 0.52. These 14 studies were from Florida, Virginia, and North Carolina in the U.S., and from India, Indonesia, Australia, and Japan. The mean HI (±S.D.) was 0.45 ± 0.04.

The objective of the present study was to quantify LAI development, *k*, RUE, and HI of some common U.S. peanut cultivars at three sites in Texas, comparing them to published values derived in other regions to investigate whether such parameters are stable across diverse regions. Such quantification of these key parameters will enable their simulation in Texas and similar areas by process-oriented crop models. In addition, this will offer a process-based system of comparing crop performance of peanut cultivars.

2. Materials and methods

Four common runner market type peanut cultivars were planted at the Texas Agric. Exp. Sta.(32°13′N, 98°12′W; 399 m above sea level) at Stephenville, TX on 1 June 2001. The cultivars were Tamrun 96 (hereafter referred to as TR96), Florunner, and Flavor Runner 458 (hereafter referred to as Flavor) and Georgia Green. These were planted at 22.3 seeds m^{-2} in 0.91 m rows on a Windthorst fine sandy loam (fine, mixed, thermic Udic Paleustalf). Plots received 50 kg N, P, and K ha^{-1} as Triple 15 and 17 kg N ha^{-1} as ammonium nitrate. All fertilizer was incorporated before planting. On 1 May 2001, TR96 was sown on a farmer's field near Gustine, TX (31°51′N, 98°24′W; 421 m above sea level) on an Abilene loam soil (fine, mixed, thermic Pachic Argiustoll). Plots were planted at the same planting rate and with the same row spacing as the Stephenville plots. Plots received 78 kg N ha^{-1} as 28-0-0-4 before the previous year's maize silage planting and no additional fertilizer thereafter.

In 2002, TR96, Florunner, and Flavor were planted at the Western Peanut Growers Research Farm near Seminole, TX in an experiment with three replications and two irrigation treatments, Spray and Low-Energy Precise Application (LEPA). The soil was a Brownfield fine sand (loamy, mixed, superactive, thermic Arenic Aridic Paleustalf). Plots were planted on 25–30 April at 18.3 seeds m^{-2} in 0.91 m rows. Plots received 34 kg N ha^{-1}, 27 kg P ha^{-1} applied as a liquid on 18 April and incorporated into the soil and 27 kg N ha^{-1} and 4.5 kg K ha^{-1} as 28-0-4 applied by the irrigation system on 24 June and 24 July.

We measured photosynthetically active radiation (PAR) interception during the season at Gustine and Stephenville with a 0.8-m-long Sunfleck Ceptometer (Decagon, Pullman, WA). In each replication, we took three series of measurements in rapid succession. A series of measurements consisted of 10 PAR measurements above the canopy, 10 below the canopy, and 10 more above the canopy. The fraction of PAR intercepted was calculated with the mean of the measurements above and below the canopy. While taking the readings below the canopy, the light meter was moved across the plant rows. Measurements were taken between 10:20 and 12:00 h local time during times with relatively stable incident solar radiation (without intermittent clouds). Daily incident PAR values were taken as 45% of the total solar radiation measured at each location (Monteith, 1965; Meek et al., 1984).

Whole plants were harvested for measuring LAI and dry weight on each day the light interception was measured. Samples consisted of a half-meter of row per replication per cultivar. One half meter of row from each plot was harvested after maturity for determining HI. Leaf areas of the samples were measured with a LiCor LI-3100 leaf area meter (LiCor Inc., Lincoln, Nebraska). Weights of the total above ground plant and the pods were measured after drying in a forced-air drying oven at 70 °C until the weight stabilized. Pods were separated from a subsample of the plants from each replication and the fraction of plant weight, which was pods, was measured. For the final harvests, seeds were separated from pods, to get the HI, defined by seed weight divided by total plant weight.

Regressions were fit with the treatment means of plant dry weight and summed IPAR for each replication. The RUE is the slope of the regression for this plant weight (g m^{-2}) as a function of the summed IPAR (MJ m^{-2}). As described above, the pod weight portion of plant weight was multiplied by a 1.65 energy correction factor. For cultivars TR96, Florunner, and Flavor, using indicator variables for slopes and intercepts, we tested to see if regressions for Gustine, and LEPA or spray irrigation treatments at Seminole differed significantly from the Stephenville data at the 95% confidence level. This involved four data sets for TR96 and three for the other two cultivars. Each data set other than Stephenville's was assigned indicator variables for slope and intercept, their values being 1.0 for that data set and 0.0 for the other data sets. Significance of the regression parameter corresponding to an indicator variable indicated that the slope or the intercept for the data set was significantly different from that of Stephenville (Neter et al., 1985).

The light extinction coefficient (k) for Beer's law (Monsi and Saeki, 1953) was calculated from the fraction of PAR intercepted (FIPAR) and the LAI. Values for k were calculated for each harvest date of each cultivar as:

$$k = \frac{[\log n(1 - \text{FIPAR})]}{\text{LAI}} \tag{1}$$

Using the measured values for each replication of each cultivar, means and S.D. values were calculated for LAI, k, and harvest index.

To compare environmental conditions among data sets, mean incident solar radiation and vapor pressure deficit (VPD) were calculated for the data sets in the literature when possible, and for the data sets in the present project. Daily values were calculated for the entire period of measurement when RUE was calculated. VPD was calculated from daily maximum and minimum temperatures using the equations of Diaz and Campbell (1988) as described by Stockle and Kiniry (1990). By not relying on relative humidity for this estimate, we avoided introducing variability due to errors in its measurement at different sites.

3. Results

3.1. LAI and light extinction coefficients (k)

Values for LAI obtained in this study were similar to those reported in the literature. Our values at Stephenville and Gustine (Table 3) increased to maximums of 5.3 to 7.0. At Seminole, maximums ranged from 4.7 to 6.2 (Table 4). Florunner had the greatest maximum at Stephenville and in the LEPA irrigation treatment at Seminole. Pooling all the data within each year, the mean maximum LAI (±S.D.) in

Table 3
Leaf area indices (LAI) and light extinction coefficients (k) for Beer's law in 2001

DAS_1, DAS_2	Location				
	Gustine (TR96[a])	Stephenville (TR96[a])	Stephenville (Florunner[a])	Stephenville (Flavor[a])	Stephenville (Georgia Green[a])
15, 32 (mean ± S.D.)					
LAI	0.06 ± 0.01	0.38 ± 0.05	0.39 ± 0.04	0.44 ± 0.02	0.68 ± 0.02
k	0.78 ± 0.11	0.52 ± 0.07	0.55 ± 0.07	0.45 ± 0.04	0.37 ± 0.01
30, 69 (mean ± S.D.)					
LAI	0.33 ± 0.06	2.64 ± 0.20	3.41 ± 0.46	4.01 ± 0.40	3.40 ± 0.38
k	0.91 ± 0.02	0.77 ± 0.04	0.69 ± 0.07	0.74 ± 0.04	0.90 ± 0.07
51, 80 (mean ± S.D.)					
LAI	2.61 ± 0.32	4.70 ± 0.44	6.13 ± 0.64	5.64 ± 0.32	4.86 ± 0.69
k	0.58 ± 0.06	0.66 ± 0.03	0.58 ± 0.04	0.68 ± 0.04	0.59 ± 0.04
63, 117 (mean ± S.D.)					
LAI	5.07 ± 0.19	6.51 ± 0.07	7.02 ± 0.57	6.65 ± 0.47	5.55 ± 0.46
k	0.62 ± 0.04	0.55 ± 0.03	0.59 ± 0.06	0.58 ± 0.04	0.70 ± 0.09
87 (mean ± S.D.)					
LAI	5.26 ± 0.76	–	–	–	–
k	0.94 ± 0.12	–	–	–	–
Mean k	0.77	0.63	0.60	0.61	0.64

TR96: tamrun 96, Flavor: flavor runner 458, DAS_1: days after sowing at Gustine and DAS_2: days after sowing at Stephenville, mean max LAI ± S.D. = 6.20 ± 0.67 and mean k ± S.D. = 0.65 ± 0.14.
[a] Cultivar.

Table 4
Leaf area indices (LAI) in 2002 for Seminole TX, TR96 is Tamrun 96, Flavor is Flavor Runner 458 and DAS are the days after sowing

DAS	Cultivar					
	TR96		Florunner		Flavor	
	Spray[a]	LEPA[a]	Spray[a]	LEPA[a]	Spray[a]	LEPA[a]
10	0.17 ± 0.02	0.15 ± 0.01	0.32 ± 0.09	0.15 ± 0.02	0.21 ± 0.06	0.15 ± 0.03
25	0.62 ± 0.04	0.59 ± 0.03	0.54 ± 0.04	0.56 ± 0.09	0.59 ± 0.06	0.46 ± 0.05
44	2.31 ± 0.23	1.91 ± 0.03	2.42 ± 0.13	2.01 ± 0.12	2.63 ± 0.44	2.20 ± 0.10
52	5.17 ± 0.42	4.63 ± 0.79	4.97 ± 0.14	5.49 ± 0.59	4.26 ± 0.21	4.10 ± 0.89
65	2.94 ± 0.31	2.95 ± 0.15	2.79 ± 0.38	2.90 ± 0.61	2.66 ± 0.41	2.87 ± 0.37
86	4.11 ± 0.21	4.29 ± 0.43	3.27 ± 0.39	4.20 ± 0.25	4.57 ± 1.03	4.22 ± 0.29
93	4.88 ± 0.66	4.92 ± 0.36	4.32 ± 0.00	6.23 ± 0.28	4.02 ± 0.27	4.74 ± 0.33
108	5.17 ± 0.54	5.09 ± 0.65	4.76 ± 0.25	5.77 ± 0.34	5.03 ± 0.24	4.42 ± 0.21

Mean max LAI ± S.D. = 5.21 ± 0.48, data values are mean ± S.D.
[a] Irrigation.

2001 was 6.20 ± 0.69 and in 2002 was 5.21 ± 0.48. These were similar to the 5.9 ± 1.5 from the 10 studies from the literature shown in Table 1.

Values of k at Stephenville and Gustine were similar to values in the literature and generally did not show consistent trends of increasing or decreasing with increasing LAI (Table 3). At Stephenville, the four cultivars had similar mean values, ranging from 0.60 to 0.64. Pooling all the data in Table 3, the mean k (±S.D.) was 0.65 ± 0.14. This was similar to the results from the eight studies in Table 1, with a mean k of 0.60 ± 0.13.

3.2. Radiation use efficiency (RUE)

An RUE value of 2.0 g MJ^{-1} of IPAR appeared to be reasonable for three of the four cultivars in this study (Figs. 1–4 and Table 5). TR96, Florunner, and Flavor at Stephenville had RUE values within 3% of 2.0. For each of these cultivars, none of the other sites or

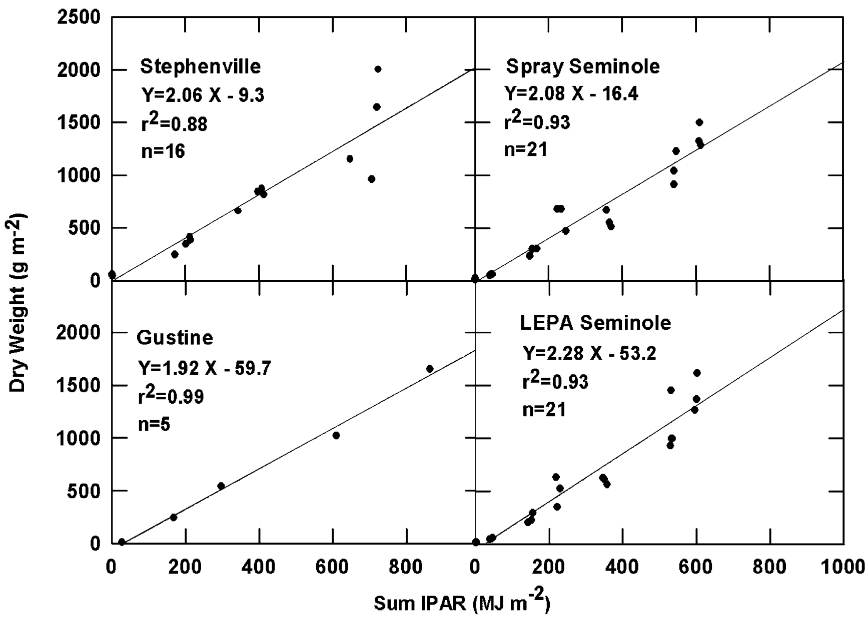

Fig. 1. For peanut cultivar TR96, dry weight as a function of summed intercepted PAR at three sites in Texas. The slope is the radiation use efficiency (RUE).

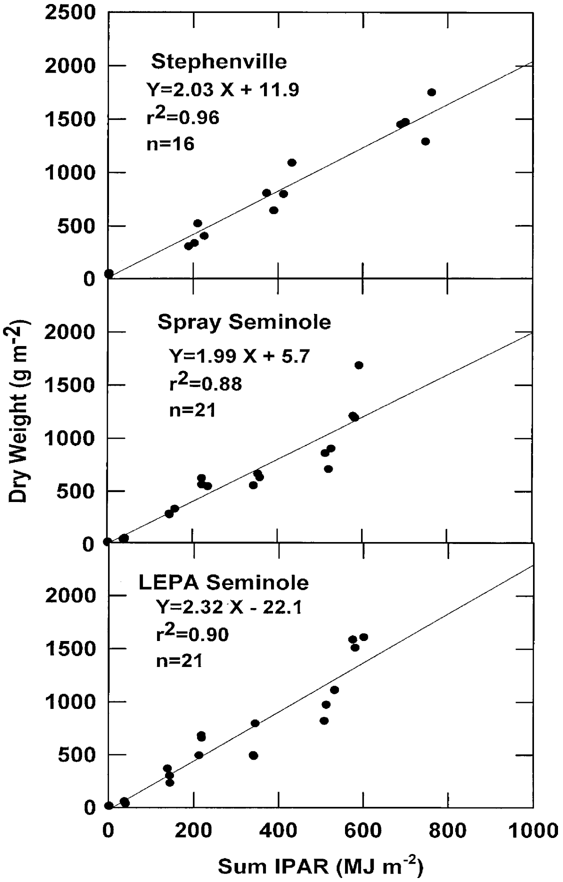

Fig. 2. For peanut cultivar Florunner, dry weight as a function of summed intercepted PAR at two sites in Texas. The slope is the radiation use efficiency (RUE).

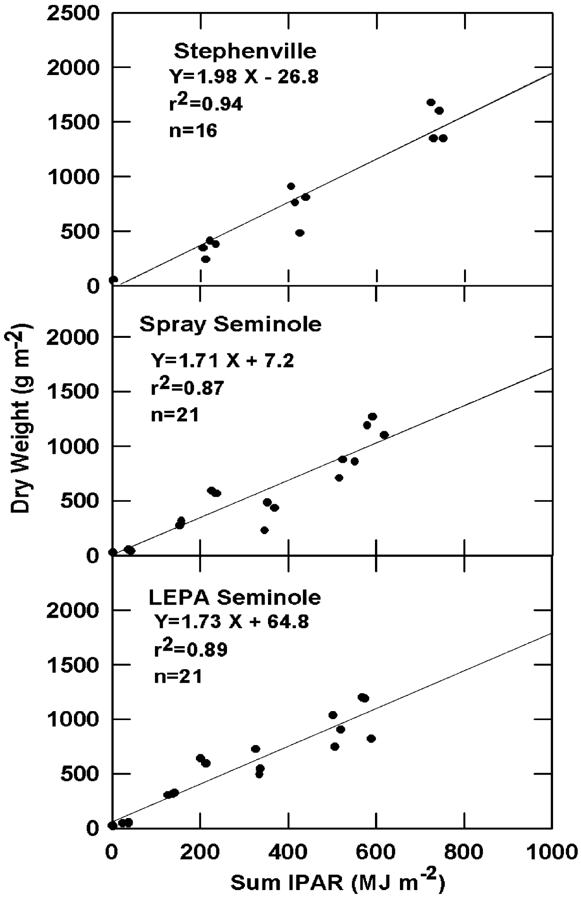

Fig. 3. For peanut cultivar Flavor, dry weight as a function of summed intercepted PAR at two sites in Texas. The slope is the radiation use efficiency (RUE).

irrigation treatments had significantly different slopes or intercepts as determined with the indicator variable analysis (results not shown). The LEPA treatment at Seminole had the largest RUE value for TR96 and Florunner, but the values were not significantly greater than those for Stephenville. Georgia Green had the lowest RUE value for Stephenville.

Compared to the four published studies with intermediate RUE values discussed above (Table 2), RUE's in the present study showed a remarkably similar mean and S.D. Pooling all the data in the present study, the mean RUE (±S.D.) was 2.00 ± 0.18 g MJ^{-1} IPAR (Table 5). For the four studies in the literature, the mean was 1.99 ± 0.20. Thus we showed similar variability among cultivars, three locations,

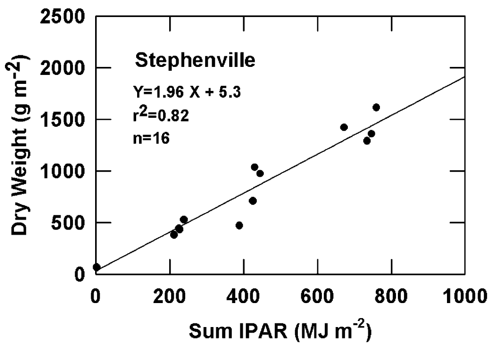

Fig. 4. For peanut cultivar Georgia Green, dry weight as a function of summed intercepted PAR at one site in Texas. The slope is the radiation use efficiency (RUE).

Table 5
Comparison of RUE values of peanut at three Texas locations in the present study

Location	VPD (kPa)	Solar radiation (MJ m^{-2})	RUE (g MJ^{-1})
Stephenville, TX	–	–	–
TR96	–	–	2.06 ± 0.20
Florunner	–	–	2.03 ± 0.11
Georgia Green	–	–	1.96 ± 0.12
Flavor	–	–	1.98 ± 0.13
Mean	1.83	–	2.01
Gustine, TX	1.65	25.6	1.92
Seminole, TX	1.61	22.7	–
Florunner Spray	–	–	1.99 ± 0.17
Florunner LEPA	–	–	2.32 ± 0.18
TR96 Spray	–	–	2.08 ± 0.13
TR96 LEPA	–	–	2.27 ± 0.15
Flavor Spray	–	–	1.71 ± 0.15
Flavor LEPA	–	–	1.73 ± 0.14
Mean	–	–	2.02

All were in the field under irrigation, mean ± S.D. using individual means 2.00 ± 0.18.

and two irrigation treatments as were shown among these studies in Australia, Canada, and Florida.

3.3. Harvest Index

Rankings among cultivars for HI were not consistent among the Stephenville measurements, the Seminole spray irrigation treatment, and the Seminole LEPA irrigation treatment (Table 6). For the three cultivars grown at both Stephenville and Seminole, TR96 had the largest HI for Stephenville, but not for the two treatments at Seminole. Cultivars in the Seminole LEPA treatment had the largest mean HI.

The mean HI for the data sets in the present study was similar to the mean of several data sets in the literature. Pooling data for all cultivars and locations in this study, the mean HI (±S.D.) was 0.46 ± 0.11. For the 14 studies in Table 1, the mean HI was 0.45 ± 0.04. Thus, a value of 0.45–0.46 is realistic for many simulation applications. However, potential for increases in HI to as much as 0.58 with efficient irrigation such as the LEPA treatment needs to be taken into account when simulating such systems.

4. Discussion

Peanut parameters described herein show varying degrees of stability across locations, environments, and irrigation treatments. Values given as means for several data sets can be used for a diversity of modeling applications. Divergent parameter values for a few data sets offer hope for yield improvement either in plant breeding programs or by improved irrigation management.

Peanuts have been extensively studied in many countries. The transfer of research findings from international studies to U.S. peanut production can benefit both modeling research and plant breeding. Results of the present study lend credence to the use of crop parameters similar to those reported elsewhere, to simulate peanut in Texas. An LAI value of 5–6 and a k value of 0.60–0.65 appear to be appropriate for peanut in many regions. Likewise, an RUE value of 2.0 should be realistic for many applications. These values appear to be reasonable for simulation in many regions of peanut production in the world.

While this study described some stability in these important aspects of peanut biomass production, yield variability due to HI differences remains a fertile area for future research on yield assessment. Simulation of environmental aspects of peanut production will rely heavily on such realistic descriptions of plant biomass production. On the other hand, yield variability among

Table 6
Harvest index results

Location	TR96	Florunner	Flavor	Georgia green	Means
Stephenville	0.34 ± 0.01	0.30 ± 0.00	0.33 ± 0.01	0.36 ± 0.01	0.33
Gustine	0.44 ± 0.01	–	–	–	0.44
Seminole(spray)	0.55 ± 0.03	0.56 ± 0.01	0.48 ± 0.03	–	0.53
Seminole(LEPA)	0.58 ± 0.02	0.59 ± 0.02	0.58 ± 0.02	–	0.58
Means	0.48	0.48	0.46	0.36	–

For all treatments, mean ± S.D.(0.46 ± 0.11).

cultivars and among irrigation types is highly dependent on HI. In this study, the LEPA treatment at Seminole had the largest HI. To improve the accuracy in peanut yield simulation, crop models need a better description of why HI varies. Research on processes affecting yield components should continue to be vigorously pursued to quantify the differences in HI observed.

Causes of the relatively large RUE values in three previously-published studies warrant further investigation. By pooling all the RUE results from the literature with those of the present study, there was no obvious trend of changing RUE with either increasing mean VPD or with increasing mean incident solar radiation. The relatively high values for VPD and for incident solar radiation at our sites in Texas appeared to not cause depressed values of RUE, as compared with values from the literature. For the three published studies with the greatest values for RUE, apparently some unidentified environmental condition caused dramatically greater RUE values.

In conclusion, some processes contributing to production of peanut biomass and yield were surprisingly stable over a diverse set of locations and cultivars in Texas and at several sites around the world. As discussed above, peanut light extinction coefficients and radiation use efficiency showed stability among many studies. Such consistency is desirable for researchers seeking to develop simulation models that are general over a wide range of conditions. However, peanut breeders desire more variable plant traits that distinguish genotypes, to be able to select for improved cultivars. Such variability was evident in the harvest index, and thus in the processes contributing to differences in harvest index among cultivars. The relatively large values for RUE in some of the published studies, as well as the larger values for two cultivars with LEPA irrigation at Seminole, raise questions that should be pursued in future research. Such increased biomass production with efficient irrigation needs to be critically investigated in light of physiological yield potential of peanut.

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References

Amthor, J.S., Loomis, R.S., 1996. Integrating knowledge of crop responses to elevated CO_2 and temperature with mechanistic simulation models: model components and research needs. In: Koch, G.W., Mooney, H.A. (Eds.), Carbon Dioxide and Terrestrial Ecosystems, Academic Press, San Diego, CA, pp. 317–345.

Awal, M.A., Ikeda, T., 2003. Controlling canopy formation, flowering, and yield in field-grown stands of peanut (*Arachis hypogaea* L.) with ambient and regulated soil temperature. Field Crops Res. 81, 131–132.

Bell, M.J., Wright, G.C., 1998. Groundnut growth and development in contrasting environments: 1. Growth and plant density responses. Expl. Agric. 34, 99–112.

Bell, M.J., Wright, G.C., Hammer, G.L., 1992. Night temperature affects radiation-use efficiency in peanut. Crop Sci. 32, 1329–1335.

Bell, M.J., Wright, G.C., Harch, G.R., 1993. Environmental and agronomic effects on the growth of four peanut cultivars in a subtropical environment I. Dry matter accumulation and radiation use efficiency. Expl. Agric. 29, 473–490.

Bell, M.J., Wright, G.C., Suryantini, Peoples, M.B., 1994. The N_2-fixing capacity of peanut cultivars with differing assimilate partitioning characteristics. Aust. J. Agric. Res. 45, 1455–1468.

Bennett, J.M., Sinclair, T.R., Li Ma, Boote, K.J., 1993. Single leaf carbon exchange and canopy radiation use efficiency of four peanut cultivars. Peanut Science 20, 1–5.

Boote, K.J., Jones, J.W., Mishoe, J.W., Wilkerson, G.G., 1986. Simulating the growth and yield of Florunner peanut. Proc. APRES 18, 38.

Chapman, S.C., Ludlow, M.M., Blamey, F.P.C., Fischer, K.S., 1993a. Effect of drought during early reproductive development on growth of cultivars of groundnut (*Arachis hypogaea* L.): I. Utilization of radiation and water during drought. . Field Crops Res. 32, 193–210.

Chapman, S.C., Ludlow, M.M., Blamey, F.P.C., Fischer, K.S., 1993b. Effect of drought during early reproductive development on growth of cultivars of groundnut (*Arachis hypogaea* L.): II. Biomass production, pod development and yield. Field Crops Res. 32, 211–225.

Coffelt, T.A., Seaton, M.L., VanScoyoc, S.W., 1989. Reproductive efficiency of 14 Virginia-type peanut cultivars. Crop Sci. 29, 1217–1220.

Collino, D.J., Dardanelli, J.L., Sereno, R., Racca, R.W., 2001. Physiological responses of Argentine peanut varieties to water stress, light interception, radiation use efficiency and partitioning of assimilates. Field Crops Res. 70, 177–184.

Diaz, R.A., Campbell, G.S., 1988. Assessment of vapor density deficit from available air temperature information. ASA Annual Meetings, Anaheim, CA. Agron. Abstr., p 16.

Duncan, W.G., McCloud, D.E., McGraw, R.L., Boote, K.J., 1978. Physiological aspects of peanut yield improvement. Crop Sci. 18, 1015–1020.

Dwivedi, S.I., Nigam, S.N., Chandra, S., Ramraj, V.M., 1998. Combining ability of biomass and harvest index under short- and long-day conditions in groundnut. Ann. Appl. Biol. 133, 237–244.

Gardner, F.P., Auma, E.O., 1989. Canopy structure, light interception, and yield and market quality of peanut genotypes as influenced by planting pattern and planting date. Field Crops Res. 20, 13–29.

Hammer, G.L., Sinclair, T.R., Boote, K.J., Wright, G.C., Meinke, H., Bell, M.J., 1995. A peanut simulation model: I.: Model development and testing. Agron. J. 87, 1085–1093.

Hang, A.N., McCloud, D.E., Boote, K.J., Duncan, W.G., 1984. Shade effects on growth, partitioning, and yield components of peanuts. Crop Sci. 24, 109–115.

Jaaffar, Z., Gardner, F.P., 1988. Canopy development, yield, and market quality in peanut as affected by genotype and planting pattern. Crop Sci. 28, 299–305.

Jones, J.W., Barfield, C.S., Boote, K.J., Smerage, G.H., Mangold, J., 1982. Photosynthetic recovery of peanuts to defoliation at various growth stages. Crop Sci. 22, 741–746.

Kaur, P., Hundal, S.S., 1999. Forecasting growth and yield of groundnut (*Arachis hypogaea*) with a dynamic simulation model ''PNUTGRO" under Punjab conditions.. J. of Agric. Science, Cambridge 133, 167–173.

Kiniry, J.R., Jones, C.A., O'Toole, J.C., Blanchet, R., Cabelguenne, M., Spanel, D.A., 1989. Radiation-use efficiency in biomass accumulation prior to grain-filling for five grain-crop species. Field Crops Res. 20, 51–64.

Kiniry, J.R., Tischler, C.R., Van Esbroeck, G.A., 1999. Radiation use efficiency and leaf CO_2 exchange for diverse C_4 grasses. Biomass and Bioenergy 17, 95–112.

Kiniry, J.R., McCauley, G., Xie, Y., Arnold, J.G., 2001. Rice parameters describing crop performance of four U.S. cultivars. Agron. J. 93, 1354–1361.

Matthews, R.B., Harris, D., Williams, J.H., Nageswara Rao, R.C., 1988. The physiological basis for yield differences between four genotypes of groundnut (*Arachis hypogaea*) in response to drought.: II. Solar radiation interception and leaf movement. Expl. Agric. 24, 203–213.

Meek, D.W., Hatfield, J.L., Howell, T.A., Idso, S.B., Reginato, R.J., 1984. A generalized relationship between photosynthetically active radiation and solar radiation. Agron. J. 76, 939–945.

Meinke, H., Hammer, G.L., 1995. A peanut simulation model: II.: Assessing regional production potential. Agron. J. 87, 1093–1099.

Monsi, M., Saeki, T., 1953. Über den lichtfaktor in den pflanzengesellschaften und seine bedeutung fur die stoffproduktion. Jpn. J. Bot. 14, 22–52.

Monteith, J.L., 1965. Radiation and crops. Exp. Agric. 1, 241–251.

Nageswara Rao, R.C., Williams, J.H., Sivakumar, M.V.K., Wadia, K.D.R., 1988. Effect of water deficit at different growth phases of peanut. II.: Response to drought during preflowering phase. Agron. J. 80, 431–438.

Neter, J., Wasserman, W., Kutner, M.H., 1985. Applied Linear Statistical Models, Irwin Press, Homewood, IL.

Pixley, K.V., Boote, K.J., Shokes, F.M., Gorbet, D.W., 1990. Growth and partitioning characteristics of four peanut genoptypes differing in resistance to late leafspot. Crop Sci. 30, 796–804.

Rosenthal, W.D., Gerik, T.J., 1991. Radiation use efficiency among cotton cultivars. Agron. J. 83, 655–658.

Selamat, A., Gardner, F.P., 1985. Growth, nitrogen uptake, and partitioning in nitrogen-fertilized nodulating and nonnodulating peanut. Agron. J. 77, 862–867.

Sinclair, T.R., Seligman, N., 2000. Criteria for publishing papers on crop modeling. Field Crops. Res. 68, 165–172.

Stockle, C.O., Kiniry, J.R., 1990. Variability in crop radiation-use efficiency associated with vapor pressure deficit. Field Crops Res. 21, 171–181.

Thornley, J.H.M., Hesketh, J.D., 1972. Growth and respiration in cotton bolls. J. Appl. Ecol. 9, 315–317.

Wells, R., Bi, T., Anderson, W.F., Wynne, J.C., 1991. Peanut yield as a result of fifty years of breeding. Agron. J. 83, 957–961.

Wright, G.C., Hubick, K.T., Farquhar, G.D., 1991. Physiological analysis of peanut cultivar response to timing and duration of drought stress. Aust. J. Agric. Res. 42, 453–470.